			Ariel.		*Umbriel.*		*Titania.*		*Oberon.*	
		G.M.T.	Pos.	Dist.	Pos.	Dist.	Pos.	Dist.	Pos.	Dist.
1882.		h.	°	"	°	"	°	"	°	"
April	9	10	—		194·9	21·1	195·7	21·0	—	
		12	—		194·8	20·9	195·6	22·7	—	
	13	8	14·7	14·4	—		17·1	11·5	—	
		10	14·5	13·1	—		16·7	13·4	—	
		12	14·2	11·3	—		16·4	15·3	—	
		18	—		—		16·0	20·6	13·4	20·9
		20	—		—		15·8	22·2	13·2	19·3
	19	16	—		—		194·7	33·8	194·1	34·6
		18	—		—		194·7	33·3	194·0	33·4
		20	—		—		194·6	32·7	193·9	32·2
	20	10	16·1	9·5	13·5	11·8	—		—	
		12	15·7	11·7	13·0	9·5	—		—	
	23	8	14·8	14·9	16·2	13·3	—		—	
		10	14·6	14·3	15·9	15·2	—		—	
	25	10	16·5	8·3	—		12·1	12·3	—	
		12	15·9	10·7	—		11·5	10·4	—	
	26	12	—		193·8	14·9	197·4	13·8	—	
		14	—		193·5	13·0	197·0	15·7	—	
		16	196·6	7·9	193·1	10·8	—		—	
		18	196·0	10·4	192·4	8·5	—		—	
May	4	8	196·0	10·9	—		—		190·8	13·1
		10	195·6	12·8	—		—		190·1	11·4

The observations of these conjunctions may serve, not only as test-observations for the theories of the motions of the satellites, but also as tests to show the power of the most powerful telescopes of the present day; and, as such conjunctions will not occur again till the year 1923, it is to be hoped that the opportunities of the coming season will not be neglected. I need scarcely add that this is also the best time for settling the question whether a fair determination of the ellipticity of *Uranus* is or is not within the reach of the best micrometrical measurements.

On the Motion of the Companion of Sirius.

By W. E. Plummer, Esq.

The history of this interesting system is too well known to need any mention here, but the recent publication in a collected form of the accurate series of observations made at the Washing-

ton Observatory makes this a fitting and easy opportunity to examine whether the observed companion is moving in an orbit resembling that in which, according to the discussion of Dr. Auwers, the perturbing body must move.

The deviation of the observed coordinates, more especially of position-angle, from those predicted by Dr. Auwers from the discussion of the proper motion of *Sirius*, has thrown some doubt on the generally received opinion of the identity of the observed companion with the perturbing body in the *Sirius* system, and recently this doubt has been somewhat strengthened by M. Flammarion, who in 1877 wrote "L'orbite apparente observée croise dès 1869 l'orbite apparente calculée et se projette en dehors suivant une toute autre courbe, qui sera plus vaste et moins excentrique."*

The deviations of the computed orbit from the observed positions made at Washington during the last few years are exhibited in the Table I. given below; and one of the objects of the present communication is to inquire how far M. Flammarion is justified in the conclusion he has drawn from these and similar data at his disposal.

TABLE I.

Date.	Observed Pos. Angle.	C−O	Observed Distance.	C−O
	°	°	″	′
1874·23	58·05	+7·08	11·11	−0·19
75·28	56·38	+6·99	11·08	−0·34
76·22	55·22	+6·47	11·19	−0·65
77·26	53·38	+6·46	10·95	−0·68
78·25	51·70	+6·22	10·76	−0·79
79·20	50·13	+5·84	10·55	−0·89
81·26	45·3	+5·9	10·0	−1·2

I have therefore collected the whole of the observations that I could find printed, being materially assisted by the series that Messrs. Gledhill, Flammarion, and Dunér had previously formed, and endeavoured to determine the ellipse that best represented the observations; that is to say, I have treated *Sirius* as an ordinary revolving star, in which case all the sinuosities of the observed path of the larger star can be neglected, since the centre of gravity of the entire system would move in a straight line, or apparently on the arc of a great circle. By the aid of Dr. Auwers' Ephemeris, corrected by the additional formula given by Dr. Dunér in 1874, a normal position-angle for the

* *Comptes Rendus*. August 13, 1877.

beginning of each year was formed. It appeared from the more recent observations that Dr. Dunér's formula, viz.

$$dP = -5^\circ.0 - 0^\circ.48\ (t - 1869.0) + 0^\circ.03\ (t - 1869.0)^2,$$

might have been, with advantage, slightly corrected, by increasing the positive term depending upon the square of the interval from 1869, but as the observations were always made near the beginning of the year, and as the angular motion was small, it was not feared that any source of inaccuracy would be introduced by using the formula as given by that astronomer. These position-angles, corrected by the formula

$$-0^\circ.006\ (t - 1870.0)$$

to remove the effect of precession, are set down in the second column of Table II.

To ascertain the probable error of these normal position-angles, it was necessary to assign some definite weight to the observations given by various observers. Not being in possession in every case of the full particulars and circumstances under which the observations were made, these weights have been assigned more or less arbitrarily, and perhaps even with fickleness. It was, to avoid this objection, at first intended to use only the results obtained at the Washington Observatory, but as this would have unhappily curtailed the period, already too short, I have been obliged to admit all. I believe that the weight has generally been over-estimated, and that the probable errors given in the third column of Table II. are consequently too small.

To determine the normal distance, I have proceeded somewhat differently. The deviation of the observed distance from the predicted had amounted in 1880 to quite a second of arc (as shown in Table I.), while in 1870 the agreement was nearly identical. The annual motion, which, therefore, in the actual orbit differed materially from that in the theoretical, was derived by means of an interpolating curve drawn among the observed distances laid down to scale. The resulting values of the normal distance with their probable errors, open to the same objection on the score of weight as in the case of the position-angles, are set down in the remaining columns of the table. In a few instances in either element the number of observations was not sufficient to determine the probable error. In the year 1881, the place given rests upon three unpublished observations made in this Observatory, and which Prof. Pritchard permits me to use for the purposes of this investigation, combined with those made at Washington, and given in the *Monthly Notices* of June last.

TABLE II.

Date.	Normal Position Angle. 1870·0.	Probable Error.	Normal Distance.	Probable Error.
	°	°	″	″
1862·0	85·13	0·09	10·18	0·042
63·0	80·97	0·41	9·64	0·117
64·0	79·76	0·59	10·35	0·157
65·0	76·52	0·25	10·18	0·227
66·0	75·61	0·38	10·49	0·347
67·0	73·73	0·52	10·36	0·398
68·0	71·01	0·36	11·17	0·078
69·0	73·80	0·88	11·22	0·012
70·0	65·48		12·06	
71·0	63·69	1·18	11·31	0·298
72·0	62·72	0·67	11·46	0·034
73·0	62·23	1·50	10·91	0·164
74·0	59·58	1·21	11·36	0·071
75·0	56·94	0·15	11·27	0·144
76·0	55·66		11·22	
77·0	53·45	0·13	11·13	0·069
78·0	52·25	0·20	10·69	0·197
79·0	49·62	0·30	10·62	0·002
80·0	48·52		10·28	
81·0	45·2		9·99	

As it is evident that no regular curve will pass through all the points determined in Table II., these were further submitted to an interpolating curve, so as derive, if possible, a series of points, which, while not differing greatly from the normal positions, might offer better prospects of successful treatment. The position-angles and distances, read from this curve, are called the "adopted position-angles" in Table III., and are the places on which all the subsequent computations have been based.

The differences from the normal positions are recorded under the headings ΔP and Δs; and it will be seen that in each coordinate, there are about eleven changes of sign out of a possible nineteen, so that the drawn curve runs sufficiently well among the observed places. The probable error has, of course, been somewhat increased, but this is immaterial, and is here given merely as a standard whereby the discrepancies that will be derived

from the comparison of places computed from various elements, with the adopted coordinates, may be compared.

TABLE III.

Date.	Adopted Position Angle.	ΔP	Prob. Error of Adopted Pos. Ang.	Adopted Distance.	Δs	Probable Error of Adopted Distance.
1862·0	85°·3	+0°·17	0°·10	9″·78	−0″·40	0″·197
63·0	82·1	+1·13	0·59	10·02	+0·38	·204
64·0	79·6	−0·16	0·71	10·25	−0·10	·653
65·0	77·2	+0·68	0·33	10·45	+0·27	·238
66·0	74·9	−0·71	0·43	10·64	+0·15	·118
67·0	72.9	−0·83	0·55	10·81	+0·45	·507
68·0	70·8	−0·21	0·49	10·97	−0·20	·119
69·0	68·9	[−4·90]	[2·56]	11·11	−0·11	·058
70·0	67·0	+1·52		11·23	−0·83	
71·0	65·1	+1·41	1·36	11·33	+0·02	·298
72·0	63·2	+0·48	0·80	11·39	−0·07	·061
73·0	61·3	−0·93	1·65	11·40	+0·49	·286
74·0	59·3	−0·28	1·22	11·38	+0·02	·072
75·0	57·4	+0·46	0·17	11·30	+0·03	·146
76·0	55·5	−0·16		11·18	−0·04	
77·0	53·6	+0·15	0·14	11·04	−0·09	·078
78·0	51·7	−0·55	0·45	10·89	+0·20	·278
79·0	49·7	+0·08	0·32	10·71	+0·09	·086
80·0	47·7	−0·82		10·48	+0·20	
81·0	45·4	+0·2		10·06	+0·07	

It will be observed that the distances indicate a tolerably well defined maximum about the year 1873, and therefore there should be a minimum as strongly pronounced, in the annual motion about the same year. This cannot be detected in the observations, and hence it is evident that two distinct orbits can be derived, according as we assume the distances as given by observation or as computed from the formula

$$r^2 \frac{d\theta}{dt} = \kappa.$$

In presence of this difficulty, I have first assumed the period to be that required by the discussion of the proper motions of *Sirius*—namely, 50 years—and with that period have derived the following orbit:—

Elements A.

Time of Periastron Passage	T =	1891·51
Excentricity	e =	0·5046
Angle between Axis Major and Node Line ...	λ =	219° 30′
Inclination	i =	55 0
Node	☊ =	48 46
Period		50 years
Mean Distance	a =	8″·32

As will be seen from Table IV., the agreement between the adopted position-angles and those computed from these elements is satisfactory. That of the distances is less so. Omitting the error for 1881, for which date the distance is insufficiently determined, the sum of the squares of the discordances expressed in hundredths of seconds is 6349, while the sum of the squares of the probable errors for the same dates, given in Table III., and expressed in the same unit, is 6117. It will be interesting, therefore, to try if the distances be better represented by a different period, and also whether the limits can be fixed between which the time of revolution must lie. With this view, the period was successively reduced to 47 and to 44 years, and by the method of varying each element a new orbit was found.

	Elements B.	Elements C.
T	1891·62	1889·44
e	0·5219	0·5908
λ	217° 13′	223° 21′
i	56 47	58 37
☊	48 12	45 27
a	8″·50	8″·53
Period	47 years	44 years

In the following table is given the comparison between the adopted places and those computed from the elements successively for each alternate year, more frequent comparisons not having been thought necessary:—

TABLE IV.

Date.	Adopted Position Angle.	C – O Elements A.	C – O Elements B.	C – O Elements C.	Adopted Distance	C – O Elements A.	C – O Elements B.	C – O Elements C.
1862·0	85°·3	–0°·2	0°·0	0°·0	9″·78	–0″·46	–0″·72	–0″·84
63·0	82·1	+0·3	+1·2	+0·2	10·02	–0·35	–0·54	–0·63
65·0	77·2	+0·2	+0·7	–0·2	10·45	–0·16	–0·23	–0·25
67·0	72·9	+0·1	+0·4	–0·3	10·81	–0·02	+0·03	+0·06
69·0	68·9	0·0	+0·1	–0·4	11·11	+0·04	+0·21	+0·26
71·0	65·1	0·0	0·0	–0·3	11·33	+0·01	+0·29	+0·37
73·0	61·3	–0·1	–0·1	–0·1	11·40	–0·03	+0·31	+0·42
75·0	57·4	0·0	–0·2	+0·2	11·30	–0·11	+0·30	+0·41
77·0	53·6	–0·3	–0·2	+0·2	11·04	–0·24	+0·20	+0·30
79·0	49·7	–0·9	0·0	–0·6	10·71	–0·45	+0·12	–0·06
81·0	45·4	–0·8	–0·5	–0·6	10·06	–0·62	–0·12	–0·47

It will be observed that the position-angle is sufficiently well represented in all three orbits, but that the distance disagrees by a greater amount than can be fairly attributed to the errors of the adopted places. The sums of the squares of the errors, which, on the assumption of a period of 50 years, amounted to 6349, rose, as the period was decreased to 47 and 44 years, to 12181 and 17312 respectively; from which it may be inferred that the period is not much less than 50 years, and certainly more than 47.

I have not been so fortunate in fixing a period which the time of revolution cannot exceed, for I find that if the period be greatly increased an entirely different set of elements will represent the observed places with fair accordance. For instance, if we assume the elements thus

$$T = 1857{\cdot}27$$
$$e = 0{\cdot}9011$$
$$\lambda = 63^\circ\ 50'$$
$$i = 75\ 58$$
$$\Omega = 93\ 35$$
$$a = 54''{\cdot}08$$

Period 442 years.

The adopted places are represented within the following errors:—

Date.			Pos. Angle. C—O	Distance. C—O
1862·0	...	...	$-0^{\circ}.4$	$-0''.17$
65·0	...	...	+0·5	+0·23
68·0	...	...	+0·6	+0·08
71·0	...	...	+0·2	−0·19
74·0	...	...	−0·1	−0·27
77·0	...	...	−0·5	+0·01
80·0	...	...	−0·8	+0·53

Doubtless these errors could have been reduced by continued computations, but no useful purpose would be served by prolonging the discussion in this direction. This approximate result is given here to exhibit a remarkable instance of the difficulty of determining the orbit of a double star when the arc of observation is not sufficiently extended. If, as in most instances, there had been no reason from independent sources to suspect a short period, these last elements would have been worthy of favourable consideration. There are, however, two circumstances which suggest their rejection. First, the elder Herschel or W. Struve never observed the duplicity of the bright star, and at the commencement of the century the position of the small star would have been

$$\theta = 283^{\circ}; \qquad s = 50'.7$$

if these latter elements are approximately correct. At such a distance from the primary it is difficult to understand how, not only Herschel, but so many astronomers failed to observe it. Secondly, with a parallax of $0''.193$, which is that assigned to *Sirius* by Dr. Gyldén, the mass of the system would be more than one hundred times the mass of the Sun. This, too, is very noticeable in relation to the masses of other stars which have been hitherto approximately determined. The argument drawn from considerations of annual parallax is, however, inconclusive, because a not impossible increase in the value deduced by Dr. Gyldén would reduce the mass of the system within probable limits. And, moreover, if the parallax furnishes a reason for the rejection of the longer period, it offers as great a difficulty to the acceptance of the shorter. For, using the same value of the parallax and adopting the mean distance given in Elements A, the resulting value of the mass of the *Sirius* system is some 32 times that of the Sun. But Dr. Auwers has shown that the perturbing body has a mass of about one-half that of *Sirius*. This makes the mass of the companion about ten times that of the Sun, whence we should expect a more conspicuous object than the satellite presents.

The conclusion to which we are driven is that, notwithstanding that observations of this interesting system have been made

for nearly twenty-years, or during two-fifths of the entire period of the motion of *Sirius*, they do no more than render the connection extremely probable, and will as yet not decide definitely whether this companion be the perturbing body or another member of a more complex system. But as the Elements A differ from those given by Dr. Auwers, it is desirable to trace what effect these alterations of the elements have in explaining the irregularities of the observed Right Ascension and Declination of *Sirius*. This is a question to which I hope to return at a future opportunity.

Oxford University Observatory:
1881, *December* 8.

Note on Messrs. Campbell and Neison's Paper on the Parallactic Inequality, in the Supplementary Number of the Monthly Notices. By E. J. Stone, M.A., F.R.S.

I. Messrs. Campbell and Neison appear willing to leave the discussion of their treatment of the question of the irradiational enlargement of the Moon as it stands. I gladly accept their decision on this point: I am quite content to leave the discussion as it stands.

II. But I cannot allow to pass unchallenged the statements which Messrs. Campbell and Neison have been pleased to make respecting the correction which the Meridian Observations of the Moon, 1851–1858, as given in the Greenwich volume, 1859, require for the error of adopted semi-diameter.

The adopted semi-diameter is clearly stated by Sir G. B. Airy to be Adams's value. The following are the corrections which I have deduced from a discussion of the observed durations 1851–1858:—

Year.	No. of Observations.	Adams's value too large by
1851	7	+0″·43
1852	3	−0·71
1853	4	−0·97
1854	3	+1·17
1855	3	+0·94
1856	3	+1·77
1857	3	+0·76
1858	5	+1·02

The deduction of these values is troublesome, and requires some care, on account of the many changes which were made in the adopted quantities of the *Nautical Almanac*, 1851–1855. But, although the results for 1852 and 1853 are rather discordant, I